Travel Behavior and Sustainability: Opportunities for ITS

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Background

Minnesotans drive about 43.3 billion miles per year--enough for about 465 trips to the sun (1). And we don't appear to be slowing down. The number of miles that we travel continues to grow by about 2% per year, a growth trend that is supported by the continued provision of new roadway capacity (2). Our transportation patterns, while reflective of our unparalleled mobility, lead to the consumption of billions of barrels of oil every day, the generation of air pollution, greenhouse gas emissions, the elimination of open space, and the eventual retirement of old cars and accessories. By some estimates, the social costs associated with all this driving amount to between $300 billion and $1.6 trillion per year in the United States alone (3).

As our understanding of these costs has increased, the urgency to reduce them as a means to supporting sustainable development has also grown. This has become increasingly evident in recent years, with President Clinton's creation of a federal advisory committee to address automobile-generated greenhouse gas emissions(4), and the formation of an Energy and Transportation Task Force within the President's Council on Sustainable Development--the broad-based, consensus-driven governmental body established solely to develop a US strategy for promoting sustainable development. Both of these forums have focused to a large extent on how we, as a nation, travel and what we can do to reduce the impacts of our travel patterns. This is nothing new. For decades, individuals from numerous professions have viewed affecting travel behavior as critical to attaining certain goals, such as congestion relief, air quality improvement, time savings, energy conservation, street safety, downtown economic development, reducing traffic fatalities, less noise, and reduced greenhouse gas emissions, to name a few. What is new about these and other efforts is the attention paid to the application of emerging information technologies to better manage our transportation system and promote sustainability. Can these "intelligent transportation systems" (ITS) really live up to their promise as tools for sustainable communities?

Factors that Drive Travel Behavior

To answer this question, one needs to look at how travel decisions are formed before assessing whether or not ITS measures apply well or badly to managing travel behavior. Each travel decision is a response to the array of options determined by physical environs, access and mobility options, and personal characteristics. Some travel behavior is determined by land use and vehicle performance. For example, the existence of well-designed walkways makes it easier for people to travel by foot, and a vehicle's fuel efficiency or safety features may affect the amount that it is driven. These issues are dealt with in greater detail in the two other papers in this series.

This paper looks at other determinants of travel behavior, such as:

- rules (e.g. speed limits, traffic signals, and HOV lanes),
- pricing (e.g. tolls, congestion pricing, parking fees, motor fuel taxes),
- choices (e.g. ease of carpooling, availability of transit, convenience and feasibility of walking and bicycling), and
- personal characteristics (sex, age, marital status, household lifecycle, occupation, income),

and how they all can affect efforts to develop sustainable communities. Altogether, these factors constitute travel behavior and travel demand, which growing numbers of decision makers are attempting to manage. This paper will explore whether or not policy measures and technologies can change the incentives governing the use of our transportation system to attain sustainability goals, and how such measures and technologies can better serve individuals of a variety of dispositions.

The Importance of Understanding Travel Behavior

Understanding how we travel is critical to the management of our transportation system for two reasons. First, travel behavior data enable managers of transportation systems (e.g. highway, transit, freight, or intermodal systems) to anticipate immediate operational problems, manage them effectively, and provide better service to system users. A simple example is the real-time information that helicopter-riding traffic reporters announce over the radio during rush hour commutes. A more sophisticated example is the outfitting of paratransit vehicles with two-way radios to enable rider pick ups and drop offs to occur more efficiently. Second, data concerning how we travel forms the foundation for virtually all travel modeling and, in turn, strongly influence transportation infrastructure planning. The importance of travel behavior data and modeling has been reinforced over the past several decades, initially through widespread adoption by regional transportation planning bodies. Most recently, the Clean Air Act Amendments of 1990 and the Intermodal Surface Transportation Efficiency Act of 1991 have both called for the improvement of travel modeling to account for land use, intermodal and multimodal scenarios, and other new factors that will increase the quality of travel forecasts and the prudence of infrastructure and operational investments.

The importance of travel modeling and the planning that it informs cannot be overstressed. Transportation--infrastructure, operations, regulation--constitutes the largest domestic investment of public funding in the US. And the impacts of transportation planning on existing communities, especially along major transportation corridors, can and have been enormous. Increasingly, especially under the Intermodal Surface Transportation Efficiency Act, planning processes are required to consider many factors that affect travel behavior. In addition to where and when people travel, planners are asking who travels, how and why, and what potential impact these trips could have on communities. New planning efforts that consider land use, air quality, and social and economic impacts are also gaining strength.

Current Travel Trends

Much of what we know about how we travel comes from the US Department of Transportation’s Nationwide Personal Transportation Survey (NPTS) which has been conducted three times since it was first conducted in 1969 (5). During this period, the NPTS has tracked our changing travel patterns. Since 1969 overall travel has increased 40 percent for everyone: 25 percent for men, 58 percent for women, and 46 percent for people over the age of 65. Vehicle trips have increased 82 percent, from 87,284 million in 1969 to 158,927 million in 1990 (6). The average length of trips--about 9 miles--has not changed, but the average number of trips has, resulting in an 82 percent increase in vehicle miles of travel.

This increase in personal travel has been accompanied by a decline in the share of transit trips--from 2.4% in 1977 to 2.2% in 1983 to about 2% in 1990. By contrast, private vehicles accounted for 84 percent of person miles traveled in 1990, Amtrak for 0.34 percent, bicycling for 0.12 percent, and walking for 0.39 percent.

A number of other relevant trends are summarized below:

Trends in Vehicle Use

Most Americans over the age of 16 are licensed to drive (women have a higher rate of licensing than men), and more vehicles are registered to Americans than ever before. The increase in household vehicles has outpaced the increase in drivers, and all Americans are driving more: 30 percent more across all age and gender categories.

The Journey to Work
Although its overall importance in transportation planning is decreasing, the journey to work is a major factor in travel decisions. The 1990 NPTS estimated that Americans took 50 billion work trips in 1990, accounting for 27 percent of individual weekday travel. The average commute is 10.7 miles, a 26 percent increase from 1983. In 1969 the average worker drove 3,441 miles to work each year, and by 1990 this had increased to 3,828 miles. The time of the commute has increased by 10 percent to about an hour each day, round trip. Transit trips to work tend to be longer in miles and minutes than driving commutes. And walking and working at home as a share of total work travel have declined in recent years.

After years as a constant in American life -- and traditional planning -- the morning and afternoon rush hours are disappearing. Travel between 6 a.m. and 9 a.m. accounts for about 14 percent of overall travel, while travel between 9:00 a.m. and 1:00 p.m. accounts for 22 percent, and travel between 1:00 and 4:00 p.m. accounts for 22 percent.

Vehicle Use and Ridesharing
The average vehicle occupancy for the journey to work has declined since 1983, from 1.3 to 1.1. Travel to work and work-related trips had the lowest rate of occupancy of all personal travel, particularly in the central city. Social and recreational travel are associated with the highest rate.

The Aging Population
The aging of the American population and the relative good health of older Americans is reflected in the phenomenal growth in the proportion of those 65 years or older who were licensed to drive: from 44 percent in 1969 to 75 percent in 1990. According to Sandra Rosenbloom of the University of Arizona, "the elderly are the fastest-growing component of the U.S. population and the very old are the fastest growing component of the elderly." Most older Americans are licensed drivers living in low-density suburban or nonmetropolitan areas, where a car is most essential to mobility. As a group, older drivers are becoming more dependent on the automobile, are covering more distance in their automobiles, and are using public transportation less.

Women, Men, Families, and Travel
In 1990 men made up 49.3 percent of the total number of licensed drivers, but accounted for 51 percent of vehicle trips and 60 percent of vehicle miles. Women between the ages of 30 and 50 make more vehicle trips than men, however, because of child care, work, and other family responsibilities. Furthermore, the entrance of women into the workforce has been attributed to a large portion of the rise in total travel and trip making. Working women may also bear the brunt of the "sandwich generation," in which caring for elderly relatives may fall to them at the same time they are caring for a growing family. Women frequently must plan their schedules around numerous family responsibilities while retaining the flexibility to respond to emergencies. These difficulties are frustrating enough, but more women live in poverty, shrinking their options still further. Single mothers, with a median income of $13,092, earn 42 percent less than married couples of any race.

Other Trends Affecting Travel Behavior
These travel trends suggest one thing: that the steadily increasing levels of travel--especially single-occupancy vehicle travel--are likely rather difficult to change without integrated, innovative strategies to control travel demand. Other factors complicate the task. For example, land use plays a significant role in travel behavior, a fact that is increasingly being addressed in transportation modeling and planning. Land use patterns create what some experts describe as “structural dependence” on driving, because many land-use decisions, the location of homes, workplaces, stores, public spaces and lifestyles adapt to increasing car use. These patterns are mutually reinforcing, making it ever more difficult for efforts to manage travel demand to succeed. Changes in land use present individuals with different origin and destination choices, and affects the frequency, mode, purpose, and other trip characteristics. They also represent changes in “price” signals, that is, if ease of access, travel time, and other factors were priced at true social cost. Most individuals are able to perceive the value of these options when contemplating trip decisions.

For decades, transportation officials regarded land use policy as part of the solution to traffic problems--their response typically was to provide more infrastructure to relieve congestion. However, this approach has failed to address long-term congestion specifically, and transportation problems generally, because increased roadway capacity appears to attract more travel demand in metropolitan areas, which is commonly referred to as “induced demand” or “latent demand.”(7) The creation of new capacity effectively mimics changes in the value of the modal choice. And though there is little consensus in the academic community on how this affects land use, there is no question that new infrastructure enables land development and often leads it (8). These are covered in more detail in the land use article.

Alternative Modes of Transportation
The availability of alternative mobility and access options are critical to determining travel behavior. In this day of increased reliance on driving, it is easy to overlook the importance of transit, bicycling, walking and telecommunications options when thinking about travel behavior. These issues will be discussed in greater detail below.

Promoting Sustainable Development: Reducing Vehicle-Miles of Travel
Reducing the rate of growth of vehicle-miles of travel (VMT) is a goal that has been equated with sustainability--from environmental, fiscal, operational, land use, and social perspectives. In fact, the President’s Council on Sustainable Development argues that one of the indicators of progress toward sustainability is “stabilizing the number of vehicle miles traveled per person while increasing the share of trips made using alternative transportation modes.”(9) Unlike traditional supply side strategies (i.e. building new roads) for dealing with traffic problems, stabilizing VMT growth is a demand-side strategy which offers the short-term traffic management benefits that increased capacity does without increasing overall demand for driving and sprawl development. From the standpoint of sustainable development, VMT reduction has become especially urgent in the past decade. US transportation data reveal that motor vehicle fuel efficiency over twenty years has roughly doubled, and that air pollution and greenhouse gas emissions from individual cars have decreased substantially. However, these gains have been counteracted by the doubling of vehicle-miles traveled. In fact, Americans consumed about 7% more gasoline in 1990 than in 1970.

For these reasons, transportation policy experts have paid more attention to reducing the demand for travel. In the abstract, this is easy to grasp--we recognize that people don't consume roads and highways, rail lines and bus lanes per se. Rather, they want to consume the goods and services that these facilities can help them gain access to: grocery stores, doctors, jobs, recreation, day care, and schools. By giving people more opportunities to make these connections, decision makers can reduce peoples' need to drive. These opportunities include measures such as providing alternative modes of transportation (walking, bicycling, transit, telecommunications) and ensuring that the system is not only multimodal, but also integrated (intermodal). At the same time, demand can be reduced by managing the transportation system: sending price signals that reflect true social costs and benefits and using other methods to encourage non-automobile use. Collectively, these are generally known as transportation demand management (TDM) strategies.

In practice, travel demand management has proven to be very difficult to implement, because VMT increases are tied to the traditional transportation planning model, which is virtually synonymous with road and highway building. TDM represents a shift from building to managing, which has proven to be a difficult transition. Besides the issue of retraining legions of engineers to think like planners, managing the travel demand forces decision makers to do more with less, and requires them to educate the public, be flexible, and demonstrate accountability for their decisions. Also, the TDM measures implemented to date are very weak. While policy makers can point to many good examples in which specific TDM measures do work, there are no good examples that illustrate the full potential of a comprehensive, accountable, and well-managed TDM plan.

Historical Overview of Transportation Demand Management

One of the first major attempts at managing transportation demand was US DOT's 1975 Transportation System Management (TSM) regulations, which were largely a reaction to the oil crisis and the highway revolts of the early 1970s. However, TSM was a failure and since has given Transportation Demand Management strategies a bad name. The reason is that TSM added on to existing roadway building practice, rather than thoughtfully integrating measures into the transportation system. Many strategies such as carpooling, transit, park and ride facilities, and local traffic management strategies were bound for failure under TSM. They were short-term in nature, featured little or no coordination of land use with transportation, offered limited consideration of different long-range scenarios, and paid no attention to capacity enhancement or providing alternative modes. Also, at the time, long-range plans continued to focus on unconstrained VMT demand projections that formed the rationale for the expansion of capacity. This made it easy for traditional transportation planners to pursue business-as-usual because there was no need to change institutional structures to implement regulations and no need to alter the status quo approach to planning and building.
Some planners made attempts at comprehensive planning, but were quickly discouraged. And the only measures that were adopted were supportive of highway investment, for example: computerized traffic signal systems, intersection widening to boost vehicle capacity, park and ride lots, high-occupancy vehicle lanes (most were new capacity), low-budget ridesharing, and parking garages. Some bike lanes were developed, but were isolated from the rest of the system and were mainly recreational. Generally, alternative modes were largely overlooked and not integrated into the rest of the system. Land use measures, parking and vehicle restrictions, and other measures were blocked.

A second, more successful attempt at managing travel demand was California's Congestion Management Program (CMP), which was mostly a response to sharply rising levels of congestion. CMP required county level agencies to consider level of service (LOS -- measure of congestion) at specific points within the system. Specifically, it required agencies to develop a Capital Improvement Program to improve LOS at those points, had them consider TDM and trip reduction ordinances, urged consideration for land use and air quality strategies, and required them to consider highway system performance as a goal. However, CMP was not a holistic, integrated approach to travel management because it was modally focused on points of congestion along roadways (principal arterials). Also, its main strategy for congestion relief has turned out to be increased capacity.

Another more successful effort to manage transportation demand was promoted by Montgomery County, MD in response to growing population and employment. The main focus of the Montgomery County effort was congestion and growth management. It offered elements of a more robust multi-modal framework for integrating congestion management with land use. For example, new land use development approvals depend on the Transportation Improvement Program provision of adequate transportation capacity, but allow trade-offs between different modal LOS. Also, only modest levels of peak traffic congestion were allowed in car-dependent areas. Higher levels of average congestion were allowed in multimodal areas.

The Montgomery County plan was a step in the right direction because it did not focus exclusively on bottlenecks. Rather, the focus was on the overall system, as exhibited by the attention to average congestion in small areas. County planners have developed sophisticated ways of measuring LOS for different mode choices that consider the following factors: share of households and jobs within walking distance of transit; average frequency of bus and rail service; ratio of sidewalk miles to street miles; availability of bike and automobile parking at transit stations; mode share for work trips and transit access trips. It also stimulated public-private opportunities like paratransit, rideshare matching, parking incentives and disincentives, and employer subsidies for transit commuting.

Montgomery County has, however, faced its share of difficulties in implementing its transportation plan. In particular, the institutional bias toward capacity expansion and emphasis on peak-hour traffic problems have rendered strategies to be short-term. The land use and intermodal efforts have produced mixed results. The application of old congestion management techniques to the new planning model has actually backfired and allowed sprawl to occur in parts of the county and more congestion to occur near Metro stations.

Furthermore, NIMBY considerations have halted some projects. Compromises have resulted in densities great enough to produce congestion, yet not great enough to support transit and other transportation alternatives. Finally, funds for this project have proven to be unstable due to political reasons.

Clean Air Act Amendments of 1990

The Clean Air Act Amendments of 1990 provided a new sense of purpose to proponents of TDM. CAAA required steps to slow or cap the growth of VMT, including TDM implementation in seriously polluted cities. It required transportation plans and programs to contribute to annual emission reductions; mandated phased compliance with emissions reductions targets; required the establishment of a separate emission budget for mobile and stationary sources; and promoted emission trading under these budgets. Some "Transportation Control Measures" that have specifically been approved by the CAAA include:

- programs to improve public transit;
- restriction of lanes to passenger buses or other high-occupancy vehicles;
- employer-based transportation management plans and incentives;
- trip reduction ordinances;
- traffic flow improvement programs that achieve emission reductions;
- fringe and transportation corridor parking facilities serving multiple occupancy vehicle programs or transit service;
- programs to limit or restrict vehicle use in downtown areas or other areas of emission concentration particularly during periods of peak use;
- programs for the provision of all forms of high-occupancy, shared-ride services;
- programs to limit portions of road surfaces or certain sections of the metropolitan are to the use of non-motorized vehicles or pedestrian use, both as to time and place;
- programs for secure bicycle storage facilities and other facilities, including bicycles lanes, for the convenience and protection of bicyclists, in both public and private areas;
- programs to control extended idling of vehicles;
- programs to reduce motor vehicle emissions, especially cold starts;
- employer-sponsored programs to permit flexible work schedules;
- programs and ordinances to facilitate non-automobile travel, provision and utilization of mass transit, and to generally reduce the need for single-occupant vehicle travel;
- programs for new construction and major reconstruction of paths, tracks, or areas solely for the use by pedestrian or other non-motorized means of transportation;
- program to encourage the voluntary removal from use in the marketplace of pre-1980 model year light duty vehicles and pre-1980 model year light duty vehicles and light duty trucks.

While these measures have laid out the range of effective TDM actions, they have never fully been implemented. In fact, last year administration officials bowed to political pressure to stop promoting TCMs and have taken no further action.

ISTEA's Congestion Management System (CMS)

The Intermodal Surface Transportation Efficiency Act of 1991 breathed more life into transportation demand management efforts, especially through its coordination with the CAAA. ISTEA created six management systems, one of which is the Congestion Management System in cities of 200,000 or greater. Within each CMS, TDM and land use must be integrated into planning and programming. The management system provides a means for ensuring physical integrity of system and for analyzing system performance, and requires ongoing efforts to evaluate the impact of different strategies to improve performance, including those related to land use, subsidies, and pricing. For CMS to truly be effective, it must become the framework for evaluating metro transportation system performance against goals and benchmarks. It should also serve to foster consensus and encourage a mix of alternatives.

However, at this stage, efforts to implement CMS seem to perpetuate looking at TDM as an afterthought, in which measures are merely added on to existing roadway plans. Also, there appears to be no clear linkage between CMS and investment and operational decisions made in the TIP, and therefore no accountability for CMS. As a result, the CMS, while technically still a required activity for transportation agencies, has offered few strong tools to manage travel demand.

The Future of TDM

Despite the limited success of past TDM measures, proponents argue that a changing management and policy climate, coupled with new technological developments, could improve the prospects for TDM to work effectively. The US soon may not have much choice: many urban areas are finding that there is little space or funding to accommodate new capacity and that more innovative techniques need to be employed to control growth in travel.

The lessons we have learned over the history of TDM efforts are invaluable. For example, we know that TDM managers should not repeat the mistake of allowing their efforts to be sequential add-ons to an existing auto-dependent system. In addition to this holistic approach, TDM efforts should focus on long-term goals, not short-term band-aids. Also, we have learned that managing transportation from the customer's perspective helps improve service delivery for the entire transportation system and the entire trip, not just specific pockets of congestion.

Potential Effectiveness of Comprehensive Transportation Management

Many studies and research projects that conclude and suggest that TDM measures haven't been implemented properly, therefore their potential has yet to be realized. But, in order for TDM to work, we must acknowledge that the context of its implementation will determine its effect. For example, a policy climate in which the investment performance of TDM measures can be assessed has provided a boost for some efforts. A decision-making and public culture that understands how the hidden social costs of transportation manifest themselves also seems to appreciate TDM more than those that do not. Also, TDM measures rarely ever work independently. Decision makers, would be foolhardy to implement disincentives without offering people attractive travel options.

From an institutional standpoint, the early resistance to TDM measures appears to be slowly eroding, now that laws such as the Clean Air Act Amendments and ISTEA have had an opportunity to become established (though TDM has had a relatively difficult time in political arenas). But good intentions need to be matched by resources and expertise. For those implementing TDM, more capacity is needed to develop transportation, land use, air quality monitoring and modeling. Only a few of the larger metropolitan planning organizations (MPOs)have demonstrated that they can successfully operate models, let alone develop their own ones. For the most part, however, MPOs don't have the resources to do this.

At the very least, planners need to understand the limits of traditional TDM measures, which focus on peak-time work trips and long-haul trips; are compatible with roadway plans; are short term in nature; and are not coordinated with the overall transportation system and an understanding of traveler demands. If these challenges can be met, then the obstacles of entrenched institutional resistance and the lack of institutional accountability for decision making should be less difficult to overcome.

Travel Behavior Goals

However these institutional and political changes occur, there are several categories of travel behavior measures that can help stabilize VMT without compromising, or in many cases improving, access and mobility. For example, policy makers widely accept the notion that driving is dramatically underpriced in the United States, and that as a result, VMT are overconsumed. A range of studies have estimated the unaccounted social costs of highway transportation (e.g. air pollution, highway emergency services, military costs related to oil procurement, traffic accidents, etc.) in the US to amount to between $300 billion to $1.6 trillion per year. Measures that account for the hidden subsidies in automobile transportation and make it costlier to drive could level the playing field between modes and make other travel options more attractive. These could be accomplished in a variety of ways, including time-of-day (congestion) pricing, distancedbased fees (VMT fees based on odometer readings), fuel taxes, parking fees, and other methods. And making drivers pay for the hidden costs of travel would create greater incentives for travelers to carpool, take alternative modes, and perhaps even travel during uncongested periods. Some promising measures are listed below: *Measures That Level The Playing Field Between Driving And Other Modes*

- Roadway and Congestion Pricing
- Fuel Taxes
- Equal Tax Treatment of Parking and Non-Driving Employee Benefits (Commuter Choice, Cashing Out Paid Parking)
- Car Insurance Priced as a Marginal Cost, Rather than as an Average Cost (Pay-As-You-Go Insurance)

To make this "leveling of the playing field" work, measures would also have to be coordinated with measures that ensure that a mix of affordable transportation choices are available to the public, especially for those who cannot drive for physical, financial, or other reasons. And since we know from the 1990 NPTS that over a quarter of all trips are less than a mile in length and that 40 percent of trips cover less than two miles, measures that provide safe and convenient facilities for bicycle and pedestrian travel could have a dramatic impact on VMT even if only modest gains in bicycle and pedestrian travel occur. Furthermore, since over half of Americans live within two miles of public transit routes, improving bicycle and pedestrian facilities to transit stations could increase intermodal trip taking. This could be boosted by efforts to enhance the quality and frequency of transit services and attempts to ensure that connections can be made between all modes. Measures That Improve Transportation Choices

- Enhancements to Transit System
- Safe and Convenient Walkways
- Facilities for Bicyclists and Bicycles
- Encouragement of Intermodal Trip Making, Especially Bike-to-Transit Options
- Traffic Calming (Reducing the Speeds at which Cars Travel in Areas Heavily Used by Pedestrians and Bicyclists)
- Architectural, Landscape, and Aesthetic Enhancements to Encourage Pedestrian and Bicycle Travel
- Improved Telecommunications to Enable Telecommuting, Teleshopping, and Other Non-Travel Access

These pricing and alternative travel mode measures can address short-term travel behavior to achieve sustainable develop goals. However, for real gains toward sustainability to occur, longer-term land use changes also need to occur. Communities across the country are beginning to recognize metropolitan expansion as the greatest potential threat to their fiscal viability, as social service and infrastructure needs become increasingly difficult to gain access to. Sprawl also threatens environmental health and creates a geographic division between communities of different social, racial, and income classes. While any land use changes (i.e. densification and better integration) resulting from pricing and alternative mode policies are likely to take place over a very long period of time (several decades, at least), such changes need to occur if attempts at stabilizing VMT growth and its associated costs are to be work. These issues will be dealt with to a greater extent in the land use paper in this series.

ITS Activities

The emergence of information technologies and their potential application to the transportation field has given rise to a new industry: intelligent transportation systems (ITS). ITS is exciting for TDM proponents because ITS technologies could enable transportation managers to have greater operational control over the overall system, if measures are integrated with existing infrastructure and policies. The application of ITS broadens the array of measures that can influence travel behavior and eases their implementation at potentially lower costs.

ITS is generally organized in the following categories:

- Advanced Public Transit Systems
- Advanced Rural Transportation Systems
- Advanced Traveler Information Systems
- Advanced Traffic Management Systems
- Advanced Vehicle Control Systems/Automated Highway Systems
- Commercial Vehicle Operations
- Intermodal ITS
- Safety and Human Factors
- Transportation Demand Management

Several are particularly relevant to travel behavior. Advanced Public Transit Systems includes bundles of technologies that improve transit service delivery. For example, ITS measures can enable transit operators to use Automatic Vehicle Location Systems to better predict arrival times for transit vehicles. The potential of this application is particularly interesting for paratransit vehicles, which are not fixed-route systems and rely on dispatcher information to pick up and drop off customers. ITS technologies could also provide travelers with automated schedule and fare information (through kiosks, phone services, etc.) or help riders with trip planning. A number of pilot projects in southern California (Riverside and San Diego) are currently testing the performance of such technologies. Several case studies have been conducted exploring electronic payment or "smart billing" technologies which facilitate payment for travelers who either carry magnetic-stripe cards that accrue value or get billed monthly for their travel. Ultimately, smart billing would consolidate payment for a number of transit services, such as buses, subways, and paratransit, into one billing process, which would further ease travel.

Another set of ITS appellations could significantly improve the safety of the transportation system. These include mayday technologies, hazard warning technologies, and crash avoidance devices. While these are likely to have little direct impact on travel behavior, safety is a primary concern of transportation managers and some traffic problems, such as congestion, can occur as a result of traffic accidents and other hazards.

Advanced traveler information technologies cover a broad range of modes and functions. For all modes, information services can aid travelers who are lost, need help in planning their trips, or simply wish to take the guesswork out of arrival times and other information. For drivers, these technologies could make travel more efficient, particularly in unfamiliar locations. In congested conditions, travelers might be able to tap into automated traveler information to determine the easiest mode by which to travel or the most convenient time to travel before getting on the road, which prevents marginal drivers from exacerbating gridlock.

Transportation system managers can apply advanced traffic management systems (ATMS) to better manage traffic flows, prevent congestion, and improve transportation safety. Such technologies place data about current traffic flows in the hands of traffic managers who can in turn send signals (through billboard, radio, and other media) to travelers to adjust their routes or driving behavior based on existing conditions.

Advanced Vehicle Control Systems (AVCS) present a mixed bag of tools to transportation demand managers. AVCS technologies, also known as Automated Highway Systems (AHS), are designed to enable hands-off automated driving, with programmable destination and route selection and crash avoidance features built in. While in the short term, managers could benefit from the ability to orchestrate traffic patterns remotely, the prospect of such travel is almost entirely unexamined from a variety of standpoints: social impacts, operational issues (especially catastrophe prevention), environmental costs, to name a few. The importance of studying such a system is especially great with AVCS because unlike other ITS technologies that can be integrated into the existing system, they represent a new mode of travel that supplants existing travel corridors and patterns. From a travel demand standpoint, policy makers have especially serious concerns that the implementation of AVCS could lead to yet another set of "structural dependencies" on driving, and that the travel speed and congestion gains that such technologies may confer might actually increase VMT. These issues warrant additional study.

ITS and Travel Modeling

ITS could also offer benefits in the gathering of travel model data and their use. For decades, the modeling profession has been dominated by gravity models, which forecast trip generation and travel demand using data on preexisting conditions, such as number and quality of destinations, traveler characteristics, and available modes. However, a new form of travel modeling--activity-based modeling-- stands to gain the most from the real-time data collection and dissemination that ITS applications could potentially offer (10).

Conclusions

It is clear that the challenge to affect travel behavior to promote sustainable development is a daunting one, since our current travel patterns and land use practices reinforce a automobile dependent transportation system. However, it is equally clear that the range of capabilities offered by ITS represent a potential breakthrough in the implementation of transportation demand management measures. The next several years will be most critical in determining how the adoption and implementation of these technologies will occur. And proponents of transportation demand management are hopeful that ITS technologies will be integrated into the array of policy goals that drive an environmentally-sustainable transportation policy today.

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1. *Highway Statistics 1994*, Federal Highway Administration, Page V-116, Table VM-2.
2. According to Highway Statistics 1994, a majority of US roadway project funds (53% in 1994) are still being spent on capacity additions adn new routes, despite the national policy goal of spending more on system preservation.
3. For the most recent and thorough study, see Mark Delucchi, "Total Cost of Motor-Vehicle Use," *Access*, Institute for Transportation Studies, UC Davis, Spring 1996, Number 8.
4. This is officially known as the Policy Dialogue Advisory Committee to Assist in the Development of Measures to Significantly Reduce Greenhouse Gas Emissions from Personal Motor Vehicles.
5. The NPTS was first conducted by the U>S> Department of Transportation in 1969, and has been conducted three times since, most recently by telephone in 1990.
6. The NPTS distinguishes between trips made by people and those made by vehicles by using two terms, person trips adn vehicle trips. One vehicle trip can account for several or even many person trips (a carpool to work or a schoolbus trip), and a person trip may use multiple modes of transportation (a bike ride to a subway stop, then a walk at the other end -- this is referred to as a segmented trip). Throughout most of the NPTS person trips are measured by the dominant mode of travel used by the individual, although segmented trips are now counted. Segmented trips are defined by the use of public transportation on at least one trip leg.
7. Mark Hansen, "Do New Highways Generate Traffic?" *Access*, University of California Transportation Center, Fall 1995, Number 7.
8. See Genevieve Giuliano, "The Weakening Transportation-Land Use Connection," *Access*, University of California Transportation Center, Spring 1995, Number 6, and Robert Cervero and John Landis, "The Transportation-Land Use Connection Still Matters," *Access*, University of California Transportation Center, Fall 1995, Number 7.
9. *Sustainable America: A New Consensus*, Washington DC: The President's Council on Sustainable Development, February 1996, p. 54.
10. See P.B. Goodwin, *Car Use and Car Dependence: A Review and Assessment of TSU Research 1974 - 1994*, prepared for the RAC Foundation for Motoring and the Environment, April 1994.